11-28-00

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## UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR § 1.53(b))

| | |
|---|---|
| Attorney Docket No. | 4015-784 |
| First Inventor or Application Identifier | Essam Sourour |
| Title | MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM |
| Express Mail Label No. | EL659733665US |

### APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO:
Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. ☒ *Fee Transmittal Form (e.g., PTO/SB/17)
   (Submit an original and a duplicate for fee processing)
2. ☒ Specification          [Total Pages 34]
   (preferred arrangement set forth below)
   — Descriptive title to the Invention
   — Cross References to Related Applications
   — Statement Regarding Fed sponsored R & D
   — Reference to Microfiche Appendix
   — Background of the Invention
   — Brief Summary of the Invention
   — Brief Description of the Drawings (if filed)
   — Detailed Description
   — Claim(s)
   — Abstract of the Disclosure
3. ☒ Drawing(s) (35 U.S.C. 113)    [Total Sheets 10]
4. ☒ Oath or Declaration    [Total Pages 3]
   a. ☒ Newly executed (original or copy)
   b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))
      (for continuation/divisional with Box 17 completed)
      [Note Box 5 below]
      i. ☐ DELETION OF INVENTOR(S)
         Signed statement attached deleting
         inventor(s) named in the prior application,
         see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference (useable if Box 4b is checked)
   The entire disclosure of the prior application, from which a
   copy of the oath or declaration is supplied under Box 4b,
   is considered as being part of the disclosure of the
   accompanying application and is hereby incorporated by
   reference therein.

6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. ☐ Computer Readable Copy
   b. ☐ Paper Copy (identical to computer copy)
   c. ☐ Statement verifying identity of above copies

### ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 C.F.R. § 3.73(b) Statement    ☒ Power of Attorney
   (when there is an assignee)
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure    ☐ Copies of IDS
    Statement (IDS)/PTO-1449    Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)
    (Should be specifically itemized)
14. ☐ *Small Entity    ☐ Statement filed in prior application,
    Statement(s)    Status still proper and desired
15. ☐ Certified Copy of Priority Document(s)
    (if foreign priority is claimed)
16. ☒ Other: Express Mail Certification

*NOTE FOR ITEMS 1 & 14: IN ORDER TO BE
ENTITLED TO PAY SMALL ENTITY FEES, A SMALL
ENTITY STATEMENT IS REQUIRED (37 C.F.R.
§ 1.27), EXCEPT IF ONE FILED IN A PRIOR
APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information below and in a preliminary statement:

☐ Continuation    ☐ Divisional    ☐ Continuation-in-part (CIP)    of prior application No: _____ / _____
Prior application information:    Examiner:    Group/Art Unit:

### 18. CORRESPONDENCE ADDRESS

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|---|---|---|---|---|---|
| COUNTRY | | TELEPHONE | | FAX | |

| Name (Print/Type) | David E. Bennett | Registration No. (Attorney/Agent) | 32,194 |
|---|---|---|---|
| Signature | David E. Bennett | Date | November 27, 2000 |
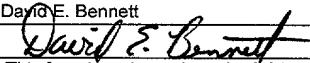
# FEE TRANSMITTAL

*Patent fees are subject to annual revision on October 1*
*These are the fees effective December 29, 1999.*
*Small Entity payments must be supported by a small entity statement.*
*otherwise large entity fees must be paid. See Forms PTO/SB/09-12.*
*See 37 C.F.R. §§ 1.27 and 1.28.*

| | Complete if Known | |
|---|---|---|
| Application Number | TBA |
| Filing Date | TBA |
| First Named Inventor | Esaam Sourour |
| Examiner Name | TBA |
| Group Art Unit | TBA |

| TOTAL AMOUNT OF PAYMENT | $1.046.00 | Attorney Docket No. | 4015-784 |
|---|---|---|---|

## METHOD OF PAYMENT (check one)

1. ☒ The Commission is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 18-1167

Deposit Account Name: Coats & Bennett, P.L.L.C.

☒ Charge Any Additional Fee Required Under 37 CFR §§1.16 and 1.17

☐ Charge the Issue Fee Set in 37 CFR §1.18 at the Mailing of the Notice of Allowance

2. ☒ Payment Enclosed:
   ☒ Check   ☐ Money Order   ☐ Other

## FEE CALCULATION

### 1. BASIC FILING FEE

| Large Fee Code | Entity Fee ($) | Small Fee Code | Entity Fee ($) | Fee Description | Fee Paid |
|---|---|---|---|---|---|
| 101 | 690 | 201 | 345 | Utility filing fee | 710.00 |
| 106 | 310 | 206 | 155 | Design filing fee | |
| 107 | 480 | 207 | 240 | Plant filing fee | |
| 108 | 760 | 208 | 380 | Reissue filing fee | |
| 114 | 150 | 214 | 75 | Provisional filing fee | |

SUBTOTAL (1) $710.00

### 2. EXTRA CLAIM FEES

| | Extra Claims | Fee from below | | Fee Paid |
|---|---|---|---|---|
| Total Claims | 32 | -20** = 12 | X 18 = | 216.00 |
| Independent Claims | 4 | -3** = 1 | X 80 = | 80.00 |
| Multiple Dependent Claims | | | X = | |

** or number previously paid, if greater; For Reissues, see below

| Large Fee Code | Entity Fee ($) | Small Fee Code | Entity Fee ($) | Fee Description |
|---|---|---|---|---|
| 103 | 18 | 203 | 9 | Claims in excess of 20 |
| 102 | 78 | 202 | 39 | Independent claims in excess of 3 |
| 104 | 260 | 204 | 130 | Multiple dependent claim |
| 109 | 78 | 209 | 39 | **Reissue independent claims over original patent |
| 110 | 18 | 210 | 9 | **Reissue claims in excess of 20 and over original patent |

SUBTOTAL (2) $296.00

## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

| Large Fee Code | Entity Fee ($) | Small Fee Code | Entity Fee ($) | Fee Description | Fee Paid |
|---|---|---|---|---|---|
| 105 | 130 | 205 | 65 | Surcharge - late filing fee or oath | |
| 127 | 50 | 227 | 25 | Surcharge - late provisional filing fee or cover sheet | |
| 139 | 130 | 139 | 130 | Non-English specification | |
| 147 | 2,520 | 147 | 2,520 | For filing a request for reexamination | |
| 112 | 920* | 112 | 920* | Requesting publication of SIR prior to Examiner action | |
| 113 | 1,840* | 113 | 1,840* | Requesting publication of SIR after Examination action | |
| 115 | 110 | 215 | 55 | Extension for reply within first month | |
| 116 | 380 | 216 | 190 | Extension for reply within second month | |
| 117 | 870 | 217 | 435 | Extension for reply within third month | |
| 118 | 1,360 | 218 | 680 | Extension for reply within fourth month | |
| 128 | 1,850 | 228 | 925 | Extension for reply within fifth month | |
| 119 | 300 | 219 | 150 | Notice of Appeal | |
| 120 | 300 | 220 | 150 | Filing a brief in support of an appeal | |
| 121 | 260 | 221 | 130 | Request for oral hearing | |
| 138 | 1,510 | 138 | 1,510 | Petition to institute a public use proceeding | |
| 140 | 110 | 240 | 55 | Petition to revive - unavoidable | |
| 141 | 1,210 | 241 | 605 | Petition to revive - unintentional | |
| 142 | 1,210 | 242 | 605 | Utility issue fee (or reissue) | |
| 143 | 430 | 243 | 215 | Design issue fee | |
| 144 | 580 | 244 | 290 | Plant issue fee | |
| 122 | 130 | 122 | 130 | Petitions to the Commissioner | |
| 123 | 50 | 123 | 50 | Petitions related to provisional applications | |
| 126 | 240 | 126 | 240 | Submission of Information Disclosure Stmt. | |
| 581 | 40 | 581 | 40 | Recording each patent assignment per property (times number of properties) | 40.00 |
| 146 | 760 | 246 | 380 | Filing a submission after final rejection (37 CFR 1.129(a)) | |
| 149 | 760 | 249 | 380 | For each additional invention to be examined (37 CFR 1.129(b)) | |

Other fee (specify) _____

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid          SUBTOTAL (3) $40.00

| SUBMITTED BY | | Complete (if applicable) | |
|---|---|---|---|
| Typed or Printed Name | David E. Bennett | Reg. Number | 32,194 |
| Signature | *David E. Bennett* | Date | 11-27-00 | Deposit Account User ID | 18-1167 |
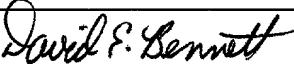
26724

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: )
)
Essam Sourour )
)
Serial No._____ )
)
Filed:_____ )
)
For: MULTIPATH INTERFERENCE )
REDUCTION FOR A CDMA SYSTEM )
)
)
Attorney's Docket No. P-4015.784 )

**Express Mail Certification
Label No.EL659733665US**

Raleigh, North Carolina

November 27, 2000

Assistant Commissioner for Patents
**BOX PATENT APPLICATION**
Washington, D.C. 20231

Sir:

## EXPRESS MAIL CERTIFICATE LABEL NO. EL659733665US
## DATE MAILED: November 27, 2000

I hereby certify that the enclosed Utility Patent Application Transmittal, Fee Transmittal Form (2 copies), specification and claims, drawings (1 set of 10 sheets), Declaration and Power Of Attorney, Assignment and Recordation Sheet, and our Check # 3097 in the amount of $1,046.00, are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. §1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, BOX PATENT APPLICATION, Washington, D.C. 20231.

Respectfully submitted,

**COATS & BENNETT, P.L.L.C.**

By:
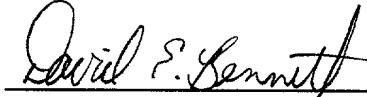
David E. Bennett
Registration No. 32,194

Telephone: (919) 854-1844

# UNITED STATES PATENT APPLICATION
# FOR GRANT OF LETTERS PATENT

## ESSAM SOUROUR
### INVENTOR

# MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM

**COATS & BENNETT, P.L.L.C.**
P.O. Box 5
Raleigh, NC  27602
(919) 854-1844

5 MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM


BACKGROUND OF THE INVENTION

The present invention relates generally to Code Division Multiple Access (CDMA)

systems and, more particularly, to reducing multipath interference in a received CDMA signal.

10 Different types of wireless communication systems have adopted various schemes for

supporting as many simultaneous users as possible. Code Division Multiple Access (CDMA) is

one such scheme. CDMA is a technique employed in spread spectrum communications

systems that allows multiple users to simultaneously share the same frequency. In CDMA

systems, a wideband spreading signal is used to convert a narrowband data signal into a

15 wideband signal for transmission. Direct sequence spread spectrum systems use a pseudo

noise (PN) sequence to spread the data signal into a wideband signal.

Modulation of the PN sequence by the data sequence may be achieved by, for example,

applying the data sequence and the PN sequence to a product modulator or multiplier.

Multiplication of two signals produces a resultant signal whose frequency spectrum is equal to

20 the convolution of the frequency spectrum of the two signals being multiplied. Thus, multiplying

the wideband PN sequence signal with the relatively narrowband data signal produces a

wideband signal whose spectrum is nearly equal to the spectrum of the PN signal.

CDMA permits multiple users to simultaneously use the same frequency by assigning to

each user a different PN code selected from a set of orthogonal codes. Transmissions to and

25 from individual users are spread using their assigned PN codes. Thus, an individual user's

signal may be recovered using his or her assigned spreading code from the combined CDMA

signal. With orthogonal spreading codes, the cross-correlation between different signals spread

using different codes is nominally zero. Thus, correlating a received CDMA signal, which

contains signals for all active users sharing that frequency, with a given user's PN code results

30 in recovery of the narrowband data signal spread with that user's PN code. Data signals

5      intended for the other active users are not de-spread by correlation, and appear as wideband noise.

In CDMA systems using orthogonal codes and relatively long spreading code sequences with respect to transmitted data symbol timing, receivers can exploit these favorable code cross-correlation properties to increase receiver performance. Improvements in performance may be

10     had even in the presence of unfavorable reception conditions, such as in multipath environments. Multipath reception commonly occurs in mobile terminals where numerous and changing obstructions intervene between the transmitter and the mobile terminals. In these cases, the transmitted CDMA signal travels to a given mobile terminal through a number of different propagation paths, with each path having different path characteristics, such as path

15     length, phase, and attenuation.

RAKE receivers are frequently used in CDMA systems, and can exploit multipath reception in many circumstances to improve reception performance. RAKE receivers accomplish this by separately processing a selected number of the multipath versions of the CDMA signal received by the mobile receiver, and then coherently combining the data signals

20     recovered from the selected multipath signals to form an overall RAKE receiver output signal with an improved signal-to-noise plus interference ratio (SNIR). RAKE receivers conventionally comprise some number of RAKE "fingers." Each RAKE finger is adapted to correlate the received CDMA signal with a commonly assigned PN code. Each RAKE finger is time-adjusted to align it with a different one of the multipath versions of the CDMA signal received by the

25     mobile receiver.

The time-alignment essentially "shifts" each RAKE finger in correspondence with a relative propagation path delay for one of the selected propagation paths. Propagation paths are generally selected based on signal strength, and a typical RAKE receiver includes only a limited number of RAKE fingers, which in operation are aligned with the most significant

30     multipath signals. The individual RAKE finger outputs are typically weighted based on the

5    propagation path characteristics of the corresponding multipath channels, and then coherently

combined to form the overall RAKE receiver output signal. Conventional RAKE receiver

techniques generally work best in environments where the total number of simultaneous users

occupying the same frequency is not too great. As the number of simultaneous users

increases, the amount of interference arising from the multipath signals influencing each other

10    increases.

## BRIEF SUMMARY OF THE INVENTION

The present invention comprises a method and system for improving receiver

performance under multipath reception conditions in CDMA-based mobile communication

15    systems. A base station transmits a CDMA forward link signal that is received by one or more

mobile terminals. Typically, an individual mobile terminal receives the transmitted signal

through a number of propagation paths, giving rise to multipath interference in the received

CDMA signal. The mobile terminal includes a modified RAKE receiver that reduces multipath

interference in the received CDMA signal.

20    The modified RAKE receiver comprises a primary RAKE function and interference

estimation RAKE function. The primary RAKE includes one or more primary RAKE fingers, with

each primary RAKE finger time aligned in accordance with a propagation path delay associated

with a propagation path through which the received CDMA signal is received. The primary

RAKE fingers each recover the user's signal of interest by correlating the received CDMA signal

25    with the user's assigned PN code sequence at a time offset corresponding to the finger's

respective propagation path. The output signals from the primary RAKE fingers are coherently

combined to form a combined signal of interest.

5    The interference estimation RAKE function generates multipath interference estimates

for each of the signals output by the primary RAKE fingers. After scaling and combining, all the

path interference estimates are subtracted from the combined signal of interest to reduce

multipath interference in the combined signal of interest. The particular order of combining and

subtracting signals of interest and interference estimates may be adjusted in accordance with

10    design needs. Generally, there are L primary RAKE fingers, each aligned to one of the L most

significant propagation paths--those paths with the strongest signal. Each one of the primary

RAKE fingers has a corresponding L -1 interference estimators within the interference

estimation RAKE function, for a total of L*(L -1) interference estimators. The ratio between

primary RAKE fingers and interference estimators may be changed in accordance with design

15    requirements.

Each interference estimator corresponds to a respective one of the primary RAKE

fingers, in turn each one of the primary RAKE fingers is time aligned with a respective one of the

propagation paths associated with the received CDMA signal. Thus, each interference

estimator estimates the multipath interference in the signal of interest recovered by its

20    respective primary RAKE finger arising from a remaining one of the multipath propagation

paths. In general, each interference estimator comprises L -1 secondary RAKE fingers, but this

ratio may be adapted as needed. Each secondary RAKE finger generates a multipath

interference estimate by correlating the received CDMA signal at a time offset determined by

path delay differences between the propagation path associated with its respective primary

25    RAKE finger and a remaining one of the propagation paths associated with the received CDMA

signal. Nominally, for L primary RAKE fingers there are L (L -1) interference estimators, and (L -

1) secondary RAKE fingers within each interference estimator.

5      The multipath interference estimates generated by the interference estimators can be coherently combined and subtracted from a combined output taken from the primary RAKE fingers. Alternative combining and subtraction schemes include but are not limited to subtracting relevant interference estimates on a per primary RAKE finger basis, and then combining the interference-compensated primary RAKE finger signals to form a combined

10     output signal of interest. In any case, the multipath interference estimates produce by the interference estimation RAKE are subtracted from the combined signal of interest produced by the primary RAKE to reduce multipath interference. The modified RAKE receiver determines appropriate scaling for the interference estimate produced by each second RAKE finger to insure that its subtraction from the combined signal of interest results in an actual reduction of

15     interference in the combined signal of interest.

Multipath interference reduction techniques employed by the modified RAKE receiver do not require knowledge of the number of simultaneous users, nor do the techniques require knowledge of any PN codes being used for the other users operating on the same frequency. Further, because multipath interference estimation in the modified RAKE receiver is based on

20     channel estimates that are readily updateable based on the pilot channel included in the CDMA forward link signal, estimation is responsive enough to deal with fast fading conditions.


BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram of an exemplary wireless communications network in which the

25     present invention may be advantageously employed.

Figure 2 is a functional diagram of a mobile terminal implementing the modified RAKE receiver of the present invention for use in the wireless communications network of Figure 1.

5      Figure 3 is a functional diagram illustrating the processing performed by the digital

modulator in the mobile terminal of Figure 2.

Figure 4 is a functional diagram illustrating the processing performed by the digital

demodulator in the mobile terminal of Figure 2.

Figure 5 is a functional diagram illustrating the modified RAKE receiver in the mobile

10     terminal of Figure 2.

Figure 6 is a diagram illustrating the mobile terminal of Figure 2 subjected to multipath

reception.

Figure 7 is a functional diagram illustrating exemplary details of the modified RAKE

receiver of Figure 5 when the number of channel paths L = 3.

15     Figure 8 is a diagram illustrating time offset components in the received composite

signal operated on by the modified RAKE receiver arising from multipath reception, with L = 3.

Figure 9 is a functional diagram illustrating exemplary details of a primary RAKE finger

used in the modified RAKE receiver of Figure 5.

Figure 10 is a functional diagram illustrating exemplary details of a secondary RAKE

20     finger used in interference estimation provided by the modified RAKE receiver of Figure 5, when

the number of channel paths L = 3.


## DETAILED DESCRIPTION OF THE INVENTION

Referring now to Figure 1, the present invention will be discussed in the context of a

25     wireless communications network supporting over-the-air communications between mobile

terminals 100 and stationary receivers generally known as base stations.  For simplicity, the

wireless communications network is depicted with only one base station 12 and associated

antenna 14; however, a practical wireless communications network will include multiple base

stations 12 to provide communications service to an extended area.  The base station 12

30     connects to a mobile switching center (MSC) 16 that connects with one or more external

5    networks 18, such as the Public Switched Telephone Network (PSTN), the Integrated Services

Digital Network (ISDN), and/or the Internet. The base station 12 is located in and provides

wireless communication services to a geographic region referred to as a cell. Generally, there

is one base station 12 for each cell within a given wireless communications network. The

wireless communications network can support communications between individual users of the

10   mobile terminals 100, and between users of the mobile terminals 100 and other communication

systems accessible through the external networks 18.

The present invention contemplates communications between the mobile terminals 100

and the base station12 based on direct sequence spread spectrum signaling employing CDMA

techniques. Interim Standard 95 (IS-95) represents an example of CDMA-based signaling. IS-

15   95 defines a wireless communications standard widely employed in North America, and in other

parts of the world. While IS-95 represents an existing cellular communications standard,

related, newer standards are under development by the Telecommunications Industry

Association (TIA), as well as by other standards bodies and industry organizations. For

example, Interim Standard 2000 known as "cdma2000," represents the next generation CDMA

20   standard currently being developed in the United States. The European variant of this standard

is referred to as Wideband CDMA (WCDMA), and is also under current development. These

named standards represent only a few of the many relevant communications standards. It

should be understood that the present invention could be adapted and employed in a variety of

communications systems extending well beyond the CDMA-based applications discussed

25   herein.

Figure 2 is a block diagram of a mobile terminal 100. The term "mobile terminal" as

used herein includes a cellular radiotelephone; a Personal Communications System (PCS)

terminal that may combine a cellular radiotelephone with data processing, facsimile and data

communications capabilities; a Personal Digital Assistant (PDA) that can include a

30   radiotelephone, pager, Internet/Intranet access, web browser, organizer, calendar; a

5      conventional lap top and/or palm top computer equipped with a radiotelephone transceiver, or

other appliance that includes a radiotelephone transceiver.  Mobile terminals may also be

referred to as "pervasive computing" devices.  The specific architecture of the mobile terminal

100 will vary depending upon the terminal's range of features and specific intended use.

The mobile terminal 100 comprises a micro controller unit (MCU) 102, an RF transceiver

10     110, a digital signal processor (DSP) 150, and a user interface 190.  The mobile terminal 100

may additionally include an external interface (not shown) for communication with the computer,

local area network, or other device.

The RF transceiver 110 establishes a link between the mobile terminal 100 and the

antenna 14 for wireless communications with the base station 12.  The RF transceiver 110

15     comprises a receiver 120, a transmitter 130, a frequency synthesizer 140, an antenna coupling

circuit 112, and an antenna 114.  The receiver 120 and transmitter 130 are coupled to the

antenna by the antenna coupling circuit 112.  The antenna coupling circuit 112 may include a

duplexer for isolating transmit and receive signal paths during full duplex receive and transmit

operations, and may include a switch for multiplexing the antenna between the receiver 120 and

20     transmitter 130 during half-duplex receive and transmit operations.  Transmit-band and receiver-

band filters in the duplexer provide the necessary isolation between receive and transmit signal

paths in the RF transceiver 110.

The receiver 120 receives a downlink or a forward link communications signal from the

base station 12.  Within a given cell, a number of mobile terminals 100 receive the same

25     forward link CDMA signal from a common base station 12.  In a given mobile terminal 100, the

receiver 120 receives the CDMA forward link signal, amplifies and down converts the received

signal to a base band frequency of the DSP 150.  Signals converted by the receiver 120 to the

base band frequency are referred to herein as base band signals.  Thus, the receiver 120

provides the DSP 150 with a base band received CDMA signal $r(t)$.  The transmitter 130 sends

30     an up link or reverse link communications signal to the base station 12.  The transmitter 130

5      receives base band signals from the DSP 150, which the transmitter 130 amplifies and uses to

modulate an RF carrier at a directed power level.

The frequency synthesizer 140 provides reference signals used for frequency translation

in the receiver 120 and the transmitter 130.

The DSP 150 comprises a source coder/decoder 160 and a digital modem 155. A

10     speech coder is included within the source coder/decoder 160 for digitizing and coding speech

for transmission on the reverse link to the base station 12. Additionally, the speech coder

decodes speech signals received from the base station 12 and converts speech signals into

audio signals that are output to the speaker 194.

The digital modem 155 processes digital signals to make communications between the

15     mobile terminal and the base station 12 more robust. The digital modem includes a digital

modulator 170 (Figure 4) and a demodulator 180 (Figure 5).

The MCU 102 supervises the operation of the mobile terminal and administers the

procedures associated with the communication protocol being used. The MCU 102 typically

comprises a microprocessor and supporting peripherals facilitating control of the mobile

20     terminal. Peripherals typically include timer/counter units, pulse-width modulation (PWM)

generators, bit-directed input/output, serial communications interfaces, and other modules for

flexibly interfacing the microprocessor with various other circuitry within the mobile terminal.

The microprocessor may include hardware computational units for accelerating certain

mathematical operations, such as division and squaring.

25     Typically, the MCU 102 assigns timers to track network time and uses that information to

assist in synchronizing the mobile terminal 100 with the required transmit and receive signal

timing. The timing information may be used to identify frame boundaries and slot indexes

associated with the received CDMA signal. The MCU 102 also uses timers to trigger specific

tasks as the mobile terminal 100 transitions to different operating modes, such as sleep,

5    receive, and talk. The MCU 102 uses register files to store calibration data, the electronic serial number (ESN) of the user (used to authenticate the user), and to other non-volatile information.

The MCU 102 also implements the communication protocols used by the mobile terminal 100. The communication protocol specifies timing, multiple access approach, modulation format, frame structure, power level, as well as many other aspects of mobile terminal

10    operation. The MCU 102 inserts signaling messages into the transmitted signals sent to the base station 12 and extracts signaling messages from the received signals. The MCU 102 acts on signaling messages received from the base station 12 as set forth in the communication protocol. When the user enters commands via the user interface 190, the commands are passed to the MCU 102 for action. The MCU 102 also provides power management to the

15    mobile terminal 100. Power management includes monitoring battery energy levels, charging the battery, and minimizing power consumption by changing modes. In general, there are three modes of operation for the mobile terminal 100: idle, receive, and talk. In idle mode, the MCU 102 deactivates most functions except the digital system clock. In receive mode the MCU 102 activates the receiver 120 and the digital modem 155. It further demodulates the paging

20    channel in the received CDMA signal until it receives a valid paging message and then switches to talk mode. In talk mode, the entire mobile terminal 100 is activated to support two-way communication.

The MCU 102 and DSP 150 use dedicated or shared buses to connect to memory (not shown). Memory is typically segmented into blocks that hold the start-up code, control software,

25    DSP firmware, and temporary data.

Figure 3 is a functional block diagram illustrating the processing performed by the digital modulator 170 in a CDMA mobile terminal 100. The digital modulator 170 comprises a convolutional encoder 171, a repeater 172, a block interleaver 173, a Walsh code generator 175, a randomizer 176, a pseudo noise generator 177, an adder 178 and an IQ modulator 179.

30    An information source, such as the user interface 190, provides an information signal, such as

5    speech or facsimile signals to the source coder/decoder 160, which converts the information

signal into digital form. The output of the source coder/decoder 160 is applied to an error

correction coder to render transmissions more tolerant to noise and interference. The error

correction encoder, may, for example, comprise the convolutional encoder 171. The error

correction coder adds controlled redundancy to the source encoded bits to aid in the detection

10   and correction of errors that occur during transmission. Detailed discussion of the processing

performed by the digital modulator 170, including operation of the Walsh modulator 175, the

randomizer 176, and the PN generator 177, is not critical to understanding the present

invention. However, the PN generator 177 may provide the assigned PN sequence to other

functions within the mobile terminal 100.

15         Figure 4 is a block diagram showing the digital demodulator 180 for a CDMA mobile

terminal 100. The digital demodulator 180 comprises a searcher 182 and associated set

maintenance list 182A, a delay tracker 183, a rake receiver 200 according to the present

invention, an automatic frequency control function (AFC) 184, an automatic gain control function

(AGC) 185, a summing circuit 186, a de-interleaver 187, and a decoder 188.

20         The searcher 182 identifies the significant propagation path signals from the active base

station 12 based on pilot channel information included in the received CDMA signal. The pilot

channel has known characteristics and allows the searcher to make rough determinations for

the relative delay offsets $\{\tau\}$ of each of the identified propagation paths. Because the pilot

channel is a known signal, the propagation path characteristics for each of the propagation

25   paths may be estimated, including path gain and phase characteristics. The propagation path

delay information determined by the searcher 182 is provided to the delay tracker 183, which

further refines the delay estimates $\{\tau\}$ such that the PN code sequence used by the RAKE

receiver 200 may be synchronized with the propagation paths of interest.

5    The delay tracker 183 also includes tracking hardware that allows the mobile terminal to keep its RAKE receiver 200 aligned with the propagation paths' potentially changing path delays. The searcher 182 also provides information regarding the set maintenance list 182A, which includes stored lists of active, neighboring, and remaining base stations 12 relevant to the current geographic position of the mobile terminal 100. As will be explained in more detail, the

10   RAKE receiver 200 correlates the received CDMA signal $r(t)$ with the user's assigned PN code and Walsh code to recover the signal of interest (the user's intended data signal) from the received CDMA signal $r(t)$. The recovered signal of interest still includes interleaving and error coding and must therefore pass through the de-interleaver 187 and the decoder 188 before the actual data signal is recovered.

15   The digital demodulator 180 provides two signals that are used to track the strength and carrier frequency of the received CDMA signal. The automatic gain control (AGC) loop adjusts the gain of the receiver 120 to overcome fading effects of the propagation channel. The automatic frequency control (AFC) loop corrects the RF synthesizer 140 to obtain the proper base band frequency after down conversion by the receiver 120.

20   Figure 5 provides top-level illustration of the RAKE receiver 200 contemplated by the present invention. The RAKE receiver 200 may be thought of as two halves, with the primary RAKE 202 operative to recover the signal of interest from the received CDMA signal $r(t)$, and the interference estimation RAKE 204 operative to generate interference estimates arising from multi-path reception of the received CDMA signal. In general operation, the interference

25   estimates produced by the interference estimation RAKE 204 are subtracted from the combined signal of interest output by the primary RAKE 202 using a summing circuit 206 to reduce multi-path interference in the combined signal of interest.

5   Figure 6 illustrates the problem of multipath reception in a mobile communications

environment. The mobile terminal 100 is subjected to multi-path reception arising from various

obstacles in and around its reception and environment. More particularly, the radio signal

transmitted by the antenna 14 associated with the base station 12 travels through a number of

different propagation paths depending upon the environmental surroundings relevant to the

10 fixed position of the base station 12 and the variable position of the mobile terminal 100.

Obstacles commonly include buildings and geographic features, as well as other types of

structures and obstructions. The radio signals transmitted from the base station antenna 14

may have a direct, line-of-site path to the mobile terminal 100, but will usually also travel to the

mobile terminal 100 via alternate propagation paths induced by the radio signal reflecting from

15 various obstructions.

   In the example illustrated, the mobile terminal 100 receives the signal transmitted by the

antenna 14 through three propagation paths, path 1, path 2, and path 3. Thus, the received

CDMA signal r(t) operated on by the RAKE receiver 200 includes multipath components

associated with path 1, path 2, and path 3. The received CDMA signal r(t) may be considered a

20 composite of its various multipath signal components. Each propagation path has particular

characteristics regarding radio signal attenuation, phase change, and mobile terminal arrival

time. The multi-path components of the received CDMA signal have different arrival times due

to the different path lengths of the various propagation paths. While the illustration depicts three

radio signal propagation paths, in practice the mobile terminal 100 may receive the transmitted

25 signal through any number of propagation paths. Typically, only a select number of these

propagation paths will be significant in terms of signal strength from the perspective of the

mobile terminal 100.

   Figure 7 provides details for the modified RAKE receiver 200 introduced in Figure 5.

The primary RAKE 202 includes one or more primary RAKE fingers 210 and an associated

30 summing circuit 212. The interference estimation RAKE 204 includes one or more interference

5    estimators 214, along with a corresponding number of scaling multipliers 216, and a summing

circuit 218.  As illustrated, the RAKE receiver 200 of the present invention is configured to

accommodate three propagation paths (paths 1, 2, and 3).  It should be understood that the

RAKE receiver 200 may be configured for any desired number of propagation paths.

In general, to accommodate $L$ propagation paths, the primary RAKE 202 will include $L$

10    primary fingers 210, while the interference estimation RAKE 204 will include $L*$ *(L-1)*

interference estimators 214.  However, the basic formula for determining the number of

interference estimators 214 needed in proportion to the number of primary RAKE fingers 210

may be changed or altered as needed, or as design restraints require.  For example, hardware

constraints may require that the total number of interference estimators 214 be reduced.  In

15    such cases, the interference estimation RAKE 204 would be scaled back to estimate

interference for only a selected number of the primary RAKE fingers 210.

In operation the primary RAKE 202 is configured such that each one of the primary

RAKE fingers 210 is assigned to one of the propagation paths of interest.  Each primary RAKE

finger 210 correlates the received CDMA signal at a time offset corresponding to a path delay

20    associated with the assigned propagation path of that primary RAKE finger 210.  Each primary

RAKE finger 210 may be time-aligned in a number of ways.  For example, the primary RAKE

fingers 210 might share delay elements (not shown) such that the received CDMA signal *r(t)*

could be appropriately delayed or time offset by values corresponding to the various

propagation path delays of interest, and then these time adjusted versions of the received

25    CDMA signal *r(t)* could be provided to the corresponding primary RAKE fingers 210.

Alternatively, the PN code and Walsh code sequences supplied to each of the primary RAKE

fingers 210 and used in their correlation operations can be offset by an amount corresponding

to the propagation path delay associated with the particular primary RAKE finger 210.

Offsetting the PN code and Walsh code sequences in this manner is often times referred to as

5      "code phase offsetting." By offsetting the PN code and Walsh code sequences, it may be more

practical to include delay elements within each of the primary RAKE fingers 210.

Figure 8 illustrates the effect of time shifting the PN code sequence in the three primary

RAKE fingers 210. The received CDMA signal $r(t)$ is correlated by the first primary RAKE finger

210 over a correlation window at time offset $\tau_1$ corresponding to path 1. The second and third

10     primary RAKE fingers 210 correlate the same received CDMA signal $r$ $(t)$ at relative time offsets

$\tau_2$ and $\tau_3$, corresponding to paths 2 and 3, respectively. The received CDMA signal $r(t)$

represents a composite of the multi-path components arising from receiving the transmitted

signal through the various propagation paths.

Referring again to Figure 7, the RAKE receiver 200 receives the currently assigned PN

15     code sequence, the set of propagation path relative delay values $\{\tau\}$, the set of propagation path

channel coefficients $\{\beta e^{j\gamma}\}$, and a set of interference estimate scale factors $\{\alpha\}$. The values for

$\{\tau\}$ and $\{\beta e^{j\gamma}\}$ may, for example, be provided by the delay tracker 183. The PN code sequence

and the assigned Walsh code in IS-95 systems may, for example, be provided by the digital

modulator 170. The primary RAKE 202 uses the relative delay values $\{\tau\}$ to align each primary

20     RAKE finger 210 in accordance with the propagation path delays. In the three-path example,

the set of relative delay values $\{\tau\}$ comprises $\tau_1$, $\tau_2$, and $\tau_3$ noted above. The set of channel

coefficients $\{\beta e^{j\gamma}\}$ comprises channel coefficients $\beta_1 e^{j\gamma}{}_1$, $\beta_2 e^{j\gamma}{}_2$, and $\beta_3 e^{j\gamma}{}_3$, corresponding to

propagation paths 1, 2, and 3, respectively. The $\beta$ values represent a magnitude value

corresponding to path gain, while the $\gamma$ values represent propagation path phase shifts. Both

25     the primary RAKE 202 and the interference estimation RAKE 204 use the set of delay values $\{\tau\}$

and the set of channel coefficients $\{\beta e^{j\gamma}\}$.

Additionally, the interference estimation RAKE 204 receives a set of scale values $\{\alpha\}$

representing multipath interference estimate signal scaling factors that are explained in more

detail later. In the three-path example, the set of scaling factors $\{\alpha\}$ comprises $\alpha_{1,2}$, $\alpha_{1,3}$, $\alpha_{2,1}$,

5    $\alpha_{2,3}$, $\alpha_{3,1}$, and $\alpha_{3,2}$, corresponding to scaling factors for each propagation path with respect to the

remaining propagation paths.

Figure 9 illustrates a primary RAKE finger 210. The primary RAKE finger 210 includes a

correlator 220 for correlating the received CDMA signal r(t) with the PN code sequence at offset

$\tau_i$ and a multiplier 222 for multiplying the received CDMA signal r(t) by the appropriate channel

10    coefficient $\beta_i e^{j\gamma}_i$, where the subscript i denotes the particular propagation path to which the

primary RAKE finger 210 is aligned. As noted, the primary RAKE finger 210 may be time

aligned to a specific one of the propagation paths by either delaying the received CDMA signal

or delaying the PN code sequence. Thus, the correlator can use the appropriate one in the set

of path delay values $\{\tau\}$ to offset the PN code sequence and Walsh code by an amount related

15    to the path delay of the corresponding propagation path. The output from the multiplier 222 is

termed the "signal of interest," and includes multipath interference arising from the other

propagation paths that becomes increasingly worse as the number of simultaneous users of

nearby mobile terminals 100 increases.

Each of the primary RAKE fingers 210 multiplies its correlator output signal by the

20    complex conjugate of the corresponding channel coefficient $\beta_i e^{j\gamma}_i$ so that the signals of interest

output by each primary RAKE finger 210 may be coherently combined together in the summing

circuit 212 to produce a combined signal of interest.

Figure 10 provides details for a selected one of the interference estimators 214 included

in the interference estimation RAKE 204. The interference estimator 214 includes secondary

25    fingers 224, a summing circuit 230, and multipliers 232 and 234. The secondary fingers 224

each include a correlator 226 and a multiplier 228. As illustrated, the interference estimator 214

is configured to estimate multipath interference arising from propagation path 2 in the signal of

interest recovered by the primary RAKE finger 210 that is aligned with propagation path 1.

Thus, the illustration continues the three-path example. As noted, each interference estimator

5    214 nominally includes L -1 secondary RAKE fingers 224. In this context, first and second

propagation path references do not necessarily imply a first and second delay relationship

between the first and second propagation paths, rather the terms are used for convenient

reference. In the illustrated example, the multipath interference arising from path 2 is

determined using correlation time offsets relative to paths 1 and 3.

10         The upper secondary RAKE finger 224 is configured to correlate the received CDMA

signal a time offset determined based on a difference between path delays corresponding to the

first and second propagation paths. Referring back to Figure 8, the upper secondary RAKE

finger 224 is configured to correlate the received CDMA signal at a time offset determined as $\tau_1$

- ($\tau_2$ - $\tau_1$), which is equivalent to correlating the received CDMA signal over a correlation window

15   that is shifted backwards from time $\tau1$ by an amount equal to the arrival time offset between

propagation paths 1 and 2. This arrival time difference may be measured as the difference

between $\tau1$ and $\tau2$.

Similarly, the lower secondary RAKE finger 224 is configured to correlate the received

CDMA signal at time offset determined based on a difference between path delays

20   corresponding to the first, second, and third propagation paths. Specifically, the correlator 226

in the lower secondary RAKE finger 224 is configured to correlate the received CDMA signal at

time offset given by $\tau_3$ - ($\tau_2$ - $\tau_1$), which is equivalent to correlating the received CDMA signal

over a correlation window that is shifted backwards from time $\tau_3$ by an amount equal to the

propagation path delay difference between propagation paths 2 and 1. This difference is

25   expressed as $\tau_2$ - $\tau_1$.

The upper secondary RAKE finger 224 is configured to multiply its correlation result with

a channel gain that is the complex conjugate of the channel gain applied by the primary RAKE

finger aligned with propagation path 1. Similarly, the lower secondary RAKE finger 224 is

configured to multiply its correlation result by the complex conjugate of the channel gain applied

5    by the primary RAKE finger aligned with propagation path 3. Multiplication of the correlation

results output from the secondary RAKE fingers 224 allows the interference estimates to be

coherently combined by summing circuit 230.

Thus, the interference estimate output by the upper secondary RAKE finger 224 may be

expressed as the correlation result $C(\tau_1 - (\tau_2 - \tau_1))$ multiplied by the complex conjugate of the

10    path 1 channel coefficient, $\beta_1 e^{-j\gamma_1}$. Similarly the interference estimate output by the lower

secondary RAKE finger 224 may be expressed as the correlation result $C(\tau_3 - (\tau_2 - \tau_1))$ multiplied

by the complex conjugate of the path 1 channel coefficient, $\beta_1 e^{-j\gamma_1}$. These two interference

estimates must be added to produce a combined interference estimate for path 1 with respect to

path 2. Using maximum ratio combining, the two interference estimates may be coherently

15    combined to form $I_{1,2}$ as,

$$I_{1,2} = \left[ \frac{C(\tau_1 - (\tau_2 - \tau_1))\beta_1 e^{-j\gamma_1} + C(\tau_3 - (\tau_2 - \tau_1))\beta_3 e^{-j\gamma_3}}{\beta_1^2 + \beta_3^2} \right] \beta_2 e^{j\gamma_2} \beta_1 e^{-j\gamma_1}$$

The above equation may be generalized for $I_{f,l}$, which represents the interference on the primary

RAKE finger 210 aligned with propagation path $f$ arising from propagation path $l$, as,

20    $$I_{f,l} = \left[ \frac{\sum_{m=1}^{L} C(\tau_m - (\tau_l - \tau_f))\beta_m e^{-j\gamma_m}}{\sum_{m=1}^{L} \beta_m^2} \right] \beta_l e^{j\gamma_l} \beta_f e^{-j\gamma_f} \qquad , m \neq l.$$

The combined multipath interference estimate output from the summing circuit 230 is

multiplied by the inverse sum of the signal powers for all propagation paths but the one for

which the interference estimate is being developed. Thus, in the illustrated example,

25    interference estimates are being developed for propagation path 2, so the signal powers for

paths 1 and 3 are summed and inverted and then used to multiply the combined interference

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5    estimate in multiplier 232. This action creates a unity-power multipath interference estimate

signal. The unity-power multipath interference estimate signal must then be scaled in

accordance with the channel coefficients for the propagation paths involved. Here, the estimate

for the interference in the propagation path 1 signal arising from the propagation path 2 signal is

being developed, so the channel coefficient corresponding to paths 1 and 2 are used. Thus,

10   multiplier 234 multiplies the unity-power multipath interference estimate signal by $\beta_2 e^{jy}{}_2 * \beta_1 e^{jy}{}_1$.

This action generates the estimated multipath interference signal, $I_{1,2}$, where $I_{1,2}$ denotes

the interference in the signal of interest produced by the primary RAKE finger 210 aligned to

path 1 arising from path 2. In general, the interference estimation RAKE 204 generates L(L - 1)

multipath interference signals, generically denoted as $I_{f,l}$, where $f$ = 1 .. L, $l$ = 1 .. L, and $f \neq l$.

15   This expression represents the interference estimate arising from the $l$ propagation path for the

signal of interest recovered from the primary RAKE finger 210 aligned with propagation path $f$.

The remaining interference estimators have similar structures that are configured with

path delay and channel coefficient values that are in accordance with their respective primary

RAKE fingers. The individual multipath interference outputs $I_{f,l}$ from all of the interference

20   estimators 214 pass through individual multipliers 216 which effect a desired scaling prior to

subtracting the interference estimates from the combined output of the primary RAKE 202.

The interference estimation technique employed by the interference estimation RAKE

204, could, absent proper care, result in adding additional interference to the combined output

of the primary RAKE 202. This possibility principally arises from the correlation window shifting

25   employed by the individual interference estimators 214. Because the correlation window shifts

used in the interference estimators 214 are not necessarily time aligned to symbol boundaries in

the received CDMA signal, correlation results include correlations across symbols, which may

result in additional interference. Thus, the interference estimation RAKE 204 employs one of

several techniques to arrive at a set of scaling factors that ensure the scaled versions of the

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5    multipath interference estimates $I_{f,l}$ produced by the interference estimators 214 accomplish the

desired function of reducing, or at least not adding interference to the combined output signal

from the primary RAKE 202.

One technique for accomplishing the above goal is to select the $\alpha$'s based on

maximizing the overall signal to noise plus interference ratio (SNIR) in the combined signal of

10    interest output by the primary RAKE 202 after subtraction of the combined interference estimate

output by the interference estimation RAKE 204. Alternately, the SNIR for individual primary

RAKE fingers 210 may be maximized. A simpler technique for accomplishing this is to set each

$\alpha_{f,l}$ (the scaling applied to $I_{f,l}$) as a ratio of the interference power and the sum of the interference

power and non-interference power for each primary RAKE finger with respect to the propagation

15    path to which the particular interference estimator 214 is concerned with. Thus, $\alpha_{f,l}$, which is the

scaling factor to be applied to $I_{f,l}$, may be determined as,

$$\alpha_{f,l} = \frac{P_x}{P_x + P_y}$$

Where a first component of $I_{f,l}$ is $x$, where $x$ is the interference that is desired to be subtracted

from the primary RAKE finger 210 aligned with propagation path $f$ caused by propagation path $l$.

20    Component $x$ has a signal power expressed as $P_x$. A second component $y$ denotes residual

terms in $I_{f,l}$ that are not interference terms in the primary RAKE finger 210 aligned with

propagation path $f$. Component y has a signal power expressed as $P_y$. The subtraction of $I_{f,l}$

removes the interference term $x$ from the signal of interest output by the respective primary

RAKE finger 210 aligned with path $f$. However, this subtraction adds the residual component $y$,

25    which was not part of the original interference. Selecting $\alpha_{f,l}$ in accordance with the above

equation, insures that the subtraction process adds less interference power than it subtracts.

The present invention may, of course, be carried out in other specific ways than those

herein set forth without departing from the spirit and essential characteristics of the invention.

5    The present embodiments are, therefore, to be considered in all respects as illustrative and not

restrictive, and all changes coming within the meaning and equivalency range of the appended

claims are intended to be embraced therein.

5                                                              CLAIMS

What is claimed is:

1.      A method of reducing multipath interference in a received composite signal

comprising a plurality of multipath signals, the method comprising:

correlating the received composite signal with a PN code sequence at a time offset

10              corresponding to a first one of the plurality of propagation paths to recover a signal of

interest from a first multipath signal;

correlating the received composite signal with the PN code sequence at a time offset

corresponding to a delay difference between the first multipath signal and a second

multipath signal to generate a multipath interference estimate;

15       subtracting the multipath interference estimate from the signal of interest to reduce

multipath interference.


2.      The method of claim 1 further comprising:

multiplying the signal of interest by a first channel coefficient determined for the first one

20              of the plurality of propagation paths to adjust a gain and phase of the signal of

interest; and

multiplying the multipath interference estimate by the first channel coefficient and by a

second channel coefficient determined for the second one of the plurality of

propagation paths before subtracting the multipath interference estimate from the

25              signal of interest to adjust a gain and phase of the multipath interference estimate.


3.      The method of claim 1 further comprising multiplying the multipath interference

estimate by an interference scaling factor before subtracting the multipath interference estimate

from the signal of interest.

5      4.      The method of claim 3 further comprising determining a value for the scaling

factor by determining a ratio of multipath interference power in the signal of interest arising from

the second multipath signal and residual interference power in the multipath interference

estimate introduced during determination of the multipath interference estimate.


10      5.      The method of claim 3 further comprising determining a value for the scaling

factor that maximizes the signal-to-noise plus interference ratio (SNIR) of the signal of interest.


6.      A method of reducing multipath interference in a received composite signal

comprising a plurality of multipath signals, the method comprising:

15          correlating the received composite signal with a PN code sequence at relative time

                offsets corresponding to path delays associated with selected ones of the plurality of

                multipath signals to recover a signal of interest from each one of the selected

                multipath signals;

        determining interference estimates for each one of the selected multipath signals caused

20              by remaining ones of the selected multipath signals by correlating the received

                composite signal at time offsets corresponding to path delay differences between the

                multipath signals;

        subtracting the interference estimates determined for the selected ones of the multipath

                signals from the signals of interest recovered from the selected ones of the multipath

25              signals.

5          7.      The method of claim 6 further comprising coherently combining the signals of

interest recovered from the selected ones of the multipath signals to form a combined signal of

interest, and wherein subtracting the interference estimates determined for selected ones of the

multipath signals from the signals of interest recovered from the selected ones of the multipath

signals comprises subtracting the interference estimates from the combined signal of interest.

10

          8.      The method of claim 6 wherein in determining an interference estimate for a first

one of the selected multipath signals caused by a second one of the selected multipath signals,

the step of determining interference estimates for each one of the selected multipath signals

caused by remaining ones of the selected multipath signals by correlating the received

15   composite signal at time offsets corresponding to path delay differences between the multipath

signals comprises:

          for all but the second multipath signal, generating a correlation output by correlating the

                  received composite signal with the PN code sequence at a time offset corresponding

                  to a current one of the selected multipath signals offset by a delay difference

20              between the first and second ones of the selected multipath signals;

          compensating each correlation output using channel coefficients determined for the

                  current one of the selected multipath signals;

          coherently combining each correlation output to form a raw estimate of the interference

                  in the first multipath signal caused by the second multipath signal;

25   multiplying the raw estimate by a power-scaling factor to adjust a power of the raw

                  estimate;

          multiplying the raw estimate by a channel-scaling factor to scale the raw estimate with

                  respect to the first and second multipath signals to form the interference estimate for

                  multipath interference in the first channel with respect to the second channel.

30

5      9.     The method of claim 8 further comprising:

scaling each of the interference estimates by a respective one in a set of interference

      estimate scalars;

combining the interference estimates after scaling by the set of interference estimate

      scalars to form a combined interference estimate;

10    combining the signals of interest to form a combined signal of interest; and

subtracting the combined interference estimate from the combined signal of interest.


10.    The method of claim 9 further comprising:

observing a characteristic dependent upon the signals of interest; and

15    updating values of the set of interference estimate scalars based on the characteristic so

      as to minimize overall multipath interference in the combined signal of interest.


11.    The method of claim 6 further comprising:

coherently combining the signals of interest to form a combined signal of interest;

20    individually scaling each of the interference estimates with a respective one of a set of

      interference estimate scalars;

combining the interference estimates after scaling by the set of interference estimate

      scalars to form a combined interference estimate; and

subtracting the combined interference estimate from the combined signal of interest to

25      reduce multipath interference in the combined signal of interest.

5    12.    The method of claim 11 further comprising:

monitoring the combined signal of interest after subtraction of the combined interference

estimate; and

adjusting values of the set of interference estimate scalars based on monitoring the

combined signal of interest to minimize a remaining amount of multipath interference

10        in the combined signal of interest after subtraction of the combined interference

estimate.


13.    The method of claim 12 wherein adjusting values of the set of interference

estimate scalars based on monitoring the combined signal of interest to minimize a remaining

15    amount of multipath interference in the combined signal of interest after subtraction of the

combined interference estimate comprises:

determining a multipath interference power value and a residual interference power

value for each interference estimate scalar in the set of interference estimates

relevant to corresponding ones of the interference estimates; and

20    setting a value of each interference estimate scalar based on a ratio involving the

respective multipath interference power value and residual interference power value;

wherein the ratio involving the multipath interference power value and residual

interference power value is adjusted to insure that the residual interference power

value is always less than the multipath interference power value.

25

14.    The method of claim 6 wherein for L selected ones of the plurality of multipath

signals, the step of determining interference estimates for each one of the selected multipath

signals caused by remaining ones of the selected multipath signals by correlating the received

composite signal at time offsets corresponding to path delay differences between the multipath

30    signals comprises determining L – 1 interference estimates for each one of the L selected

5    multipath signals, with each estimate for a current one of the L selected multipath signals

representing an estimate of multipath interference in the current selected multipath signal

caused by a remaining one of the selected multipath signals.

15.    The method of claim 14 further comprising performing L – 1 offset correlations of

10   the received composite signal for each one of the L –1 interference estimates, such that each

one of the L – 1 interference estimates generated for each one of the L interference estimates

comprises a summation of L – 1 correlation results.

16.    A RAKE receiver comprising:

15   at least one primary RAKE finger, each adapted to recover a signal of interest from a

selected multipath signal within a received composite signal comprising a plurality of

multipath signals by correlating the received composite signal with a PN code at a

time offset corresponding to the selected multipath signal;

at least one interference estimator, each adapted to generate an interference estimate

20       for a corresponding one of the at least one primary RAKE finger caused by a

remaining one of the plurality of multipath signals with respect to the selected

multipath signal from which the corresponding primary RAKE finger recovers the

signal of interest; and

a subtraction circuit for subtracting the interference estimates generated by the at least

25       one interference estimator from the signals of interest recovered by the at least one

primary RAKE finger.

5    17.    The RAKE receiver of claim 16 wherein the at least one primary RAKE finger

comprises a plurality of primary RAKE fingers, each aligned to one of a selected set of multipath

signals chosen from the plurality of multipath signals in the received composite signal and each

adapted to output a recovered signal of interest, and further wherein the at least one

interference estimator comprises a plurality of interference estimators, each adapted to

10    generate an interference estimate for a corresponding one of the plurality of primary RAKE

fingers.


18.    The RAKE receiver of claim 17 further comprising:

a signal of interest combiner to combine the signals of interest to form a combined signal

15        of interest; and

an interference estimate combiner to combine the interference estimates to form a

combined interference estimate;

wherein the subtraction circuit is operative to subtract the interference estimates

generated by the at least one interference estimator from the signals of interest

20        recovered by the at least one primary RAKE finger by subtracting the combined

interference estimate from the combined signal of interest.


19.    The RAKE receiver of claim 17 further comprising a plurality of interference

estimate scalars, each adapted to multiply a respective one of the interference estimates by one

25    in a set of interference estimate scale values in advance of the interference estimates being

subtracted from the signals of interest in the subtraction circuit.

5     20.     The RAKE receiver of claim 16 wherein each one of the at least one interference

estimators comprises:

        a plurality of secondary RAKE fingers, each adapted to generate an individual estimate

           of multipath interference in a first one of the plurality of multipath signals arising from

           a second one of the plurality of multipath signals by correlating the received

10            composite signal with the PN code sequence at time offset corresponding to a

           selected one of the plurality of multipath signals shifted by a relative delay difference

           between the first and second multipath signals, wherein the selected multipath signal

           is not the second multipath signal;

        a first multiplier in each secondary RAKE finger adapted to multiply the individual

15            estimate of multipath interference by a channel coefficient determined for the

           selected multipath signal on which the secondary RAKE finger operates;

        a combining circuit for combining the output from each secondary RAKE finger within the

           interference estimator to form a raw interference estimate;

        a second multiplier adapted to multiply the raw estimate by a power-scaling value to

20            form a power-scaled raw estimate;

        a third multiplier adapted to multiply the power-scaled raw estimate by a channel-scaling

           value to form the interference estimate output by the interference estimator.

        21.     The RAKE receiver of claim 20 wherein there are L primary RAKE fingers

25   corresponding to L selected multipath signals, and up to (L −1) interference estimators for each

one of the L primary RAKE fingers, each of the up to (L − 1) interference estimators

corresponding to a given one of the L primary RAKE fingers adapted to estimate the

interference in the selected multipath signal corresponding to the given primary RAKE finger

arising from a remaining one of the L selected multipath signals.

30

5       22.     The RAKE receiver of claim 20 wherein the RAKE receiver is further adapted to

determine the power-scaling value used in each of the at least one interference estimators

based on propagation channel coefficients determined for relevant ones of the plurality of

multipath signals.


10      23.     The RAKE receiver of claim 20 wherein the RAKE receiver is further adapted to

determine the channel scaling value used in each of the at least one interference estimators

based on propagation channel coefficients determined for the first and second multipath signals

relevant to a given one of the at least one interference estimator.


15      24.     The RAKE receiver of claim 20 further comprising a set of interference-scaling

multipliers, wherein individual ones of the interference-scaling multipliers correspond to

respective ones of the interference estimates, and wherein each interference-scaling multiplier

is adapted to multiply the respective interference estimate with a particular interference scale

value before the interference estimates are subtracted from the signals of interest.

20

        25.     The RAKE receiver of claim 16 wherein the subtraction circuit comprises a set of

individual differencing circuits, each adapted to subtract corresponding ones of the interference

estimates from each of the signals of interest.

5      26.     The RAKE receiver of claim 25 further comprising a post-subtraction combining

circuit for combining the signals of interest to form a combined signal of interest.

27.     A mobile terminal comprising:

a user interface adapted to allow a user to control the mobile terminal, and input local

10         speech signals for transmission and hear remote speech signals recovered from

receive signals;

a transmitter adapted to transmit the local speech signals to a base station via an RF

transmit signal; and

a receiver adapted to recover the remote speech signals from a received composite

15        signal; said receiver comprising:

at least one primary RAKE finger, each adapted to recover a signal of interest

from a selected multipath signal within a received composite signal

comprising a plurality of multipath signals by correlating the received

composite signal with a PN code at a time offset corresponding to the

20               selected multipath signal;

at least one interference estimator, each adapted to generate an interference

estimate for a corresponding one of the at least one primary RAKE finger

caused by a remaining one of the plurality of multipath signals with respect to

the selected multipath signal from which the corresponding primary RAKE

25               finger recovers the signal of interest; and

a subtraction circuit for subtracting the interference estimates generated by the at

least one interference estimator from the signals of interest recovered by the

at least one primary RAKE finger.

31

5    28.    The mobile terminal of claim 27 wherein each one of the at least one interference

estimators comprises:

a plurality of secondary RAKE fingers, each adapted to generate an individual estimate

of multipath interference in a first one of the plurality of multipath signals arising from

a second one of the plurality of multipath signals by correlating the received

10    composite signal with the PN code sequence at time offset corresponding to a

selected one of the plurality of multipath signals shifted by a relative delay difference

between the first and second multipath signals, wherein the selected multipath signal

is not the second multipath signal;

a first multiplier in each secondary RAKE finger adapted to multiply the individual

15    estimate of multipath interference by a channel coefficient determined for the

selected multipath signal on which the secondary RAKE finger operates;

a combining circuit for combining the output from each secondary RAKE finger within the

interference estimator to form a raw interference estimate;

a second multiplier adapted to multiply the raw estimate by a power-scaling value to

20    form a power-scaled raw estimate;

a third multiplier adapted to multiply the power-scaled raw estimate by a channel-scaling

value to form the interference estimate output by the interference estimator.


29.    The mobile terminal of claim 28 wherein there are L primary RAKE fingers

25    corresponding to L selected multipath signals, and up to (L −1) interference estimators for each

one of the L primary RAKE fingers, each of the up to (L − 1) interference estimators

corresponding to a given one of the L primary RAKE fingers adapted to estimate the

interference in the selected multipath signal corresponding to the given primary RAKE finger

arising from a remaining one of the L selected multipath signals.

30

5    30.    The mobile terminal of claim 28 wherein the RAKE receiver is further adapted to determine the power-scaling value used in each of the at least one interference estimators based on propagation channel coefficients determined for relevant ones of the plurality of multipath signals.

10    31.    The mobile terminal of claim 28 wherein the RAKE receiver is further adapted to determine the channel scaling value used in each of the at least one interference estimators based on propagation channel coefficients determined for the first and second multipath signals relevant to a given one of the at least one interference estimator.

15    32.    The mobile terminal of claim 28 further comprising a set of interference-scaling multipliers, wherein individual ones of the interference-scaling multipliers correspond to respective ones of the interference estimates, and wherein each interference-scaling multiplier is adapted to multiply the respective interference estimate with a particular interference scale value before the interference estimates are subtracted from the signals of interest.

20

5          ABSTRACT OF THE DISCLOSURE

A method and system reduce multipath signal interference in a CDMA receiver. The

CDMA receiver comprising parallel first and second RAKE receivers receives a multipath signal.

The first RAKE receiver includes a number of individual RAKE fingers, each operating with a

defined finger delay matched to a propagation path delay. The output signal from each RAKE

10     finger includes multipath interference. The second RAKE receiver includes a group of RAKE

fingers corresponding to each RAKE finger in the first RAKE receiver. Each group of RAKE

fingers is configured to produce an estimate of the multipath interference in the output signal

generated by the corresponding RAKE finger in the first RAKE receiver. The estimated

multipath interference signals are scaled, and then subtracted from the RAKE finger outputs

15     from the first RAKE receiver to reduce multipath interference. Scaling coefficients are adjusted

to ensure that such subtraction effectively reduces multipath interference.

USER 1
100

USER 2
100

USER N
100

BASE
STATION
12

MSC
16

14

EXTERNAL
NETWORK(S)
(e.g. PSTN)
18

10

*FIG. 1*

*FIG. 2*

FIG. 3

180

SET
MAINTENANCE — 182A

SEARCHER — 182

DELAY
TRACKER — 183

RAKE
RECEIVER — 200

LONG
CODE

DE-INTERLEAVER — 187

DECODER — 188

RECOVERED
DATA

⊕ — 186

AFC — 184

AGC — 185

RECEIVED
DATA

TO RF
RECEIVER

*FIG. 4*

r(t)

PRIMARY
RAKE

200

202

Σ

+

−

206

INTERFERENCE
ESTIMATION
RAKE

204

*FIG. 5*

PATH 3

PATH 1

PATH 2

100

14

12 BASE STATION

16 MSC

18 EXTERNAL NETWORK(S)
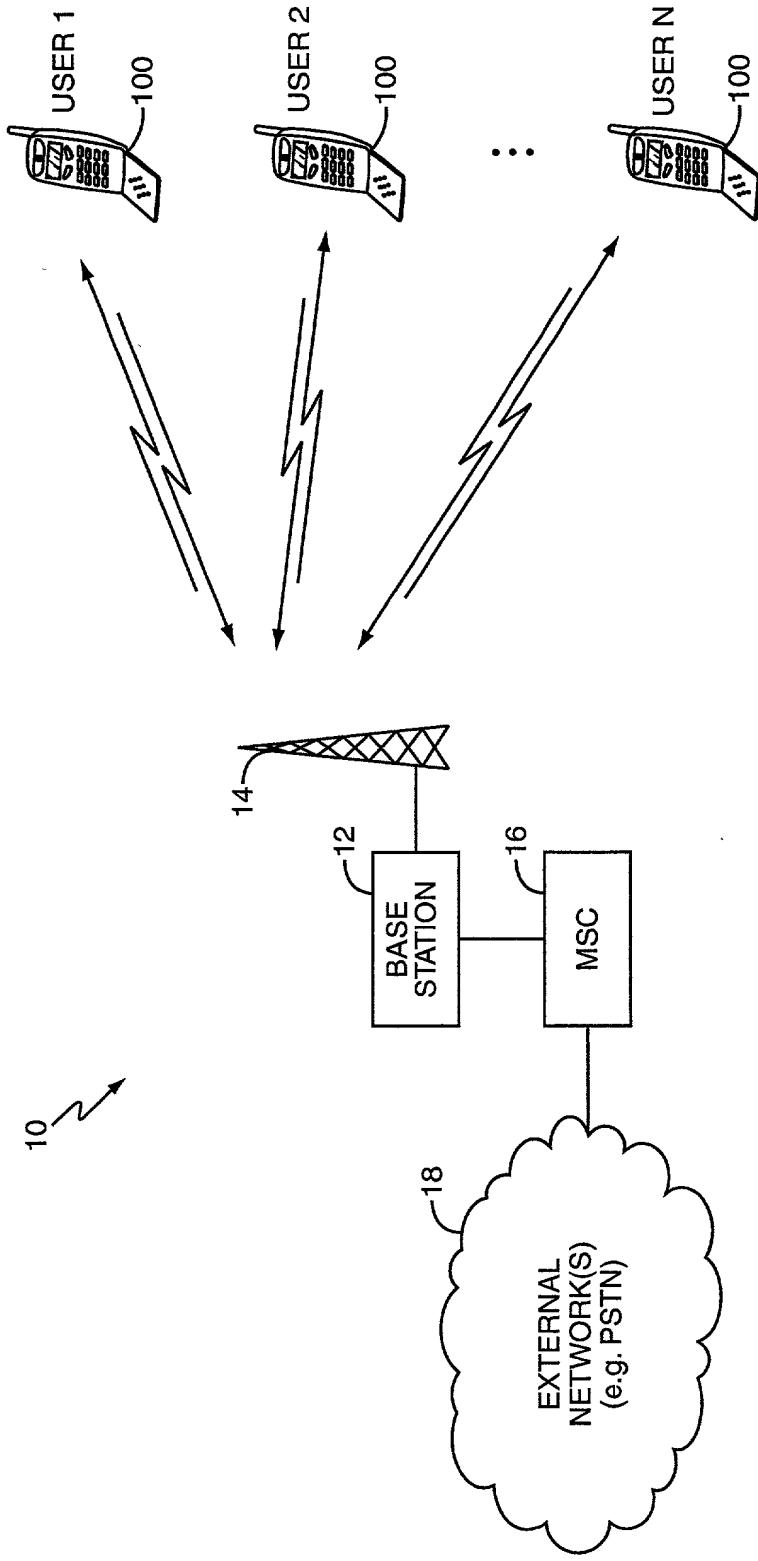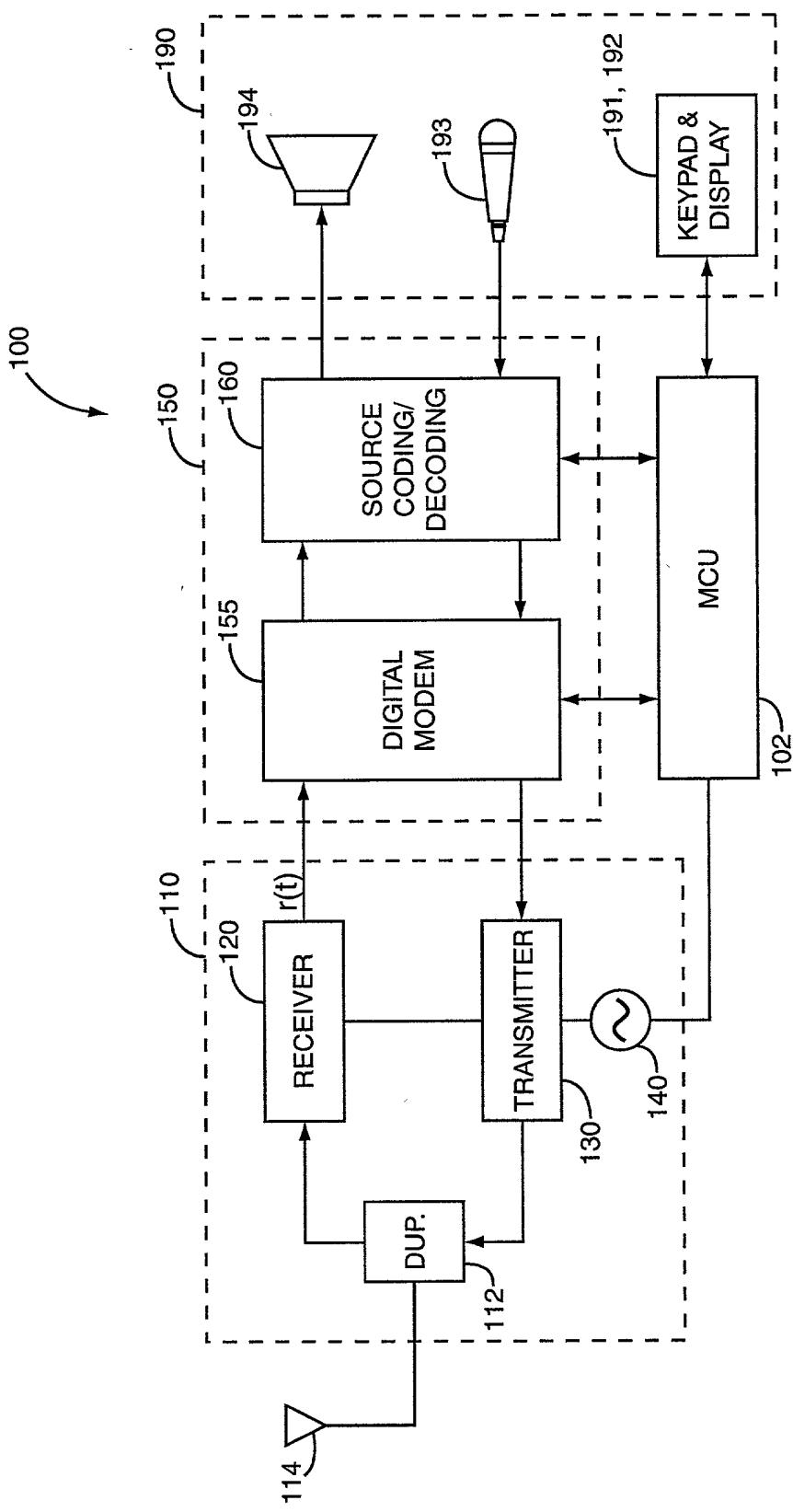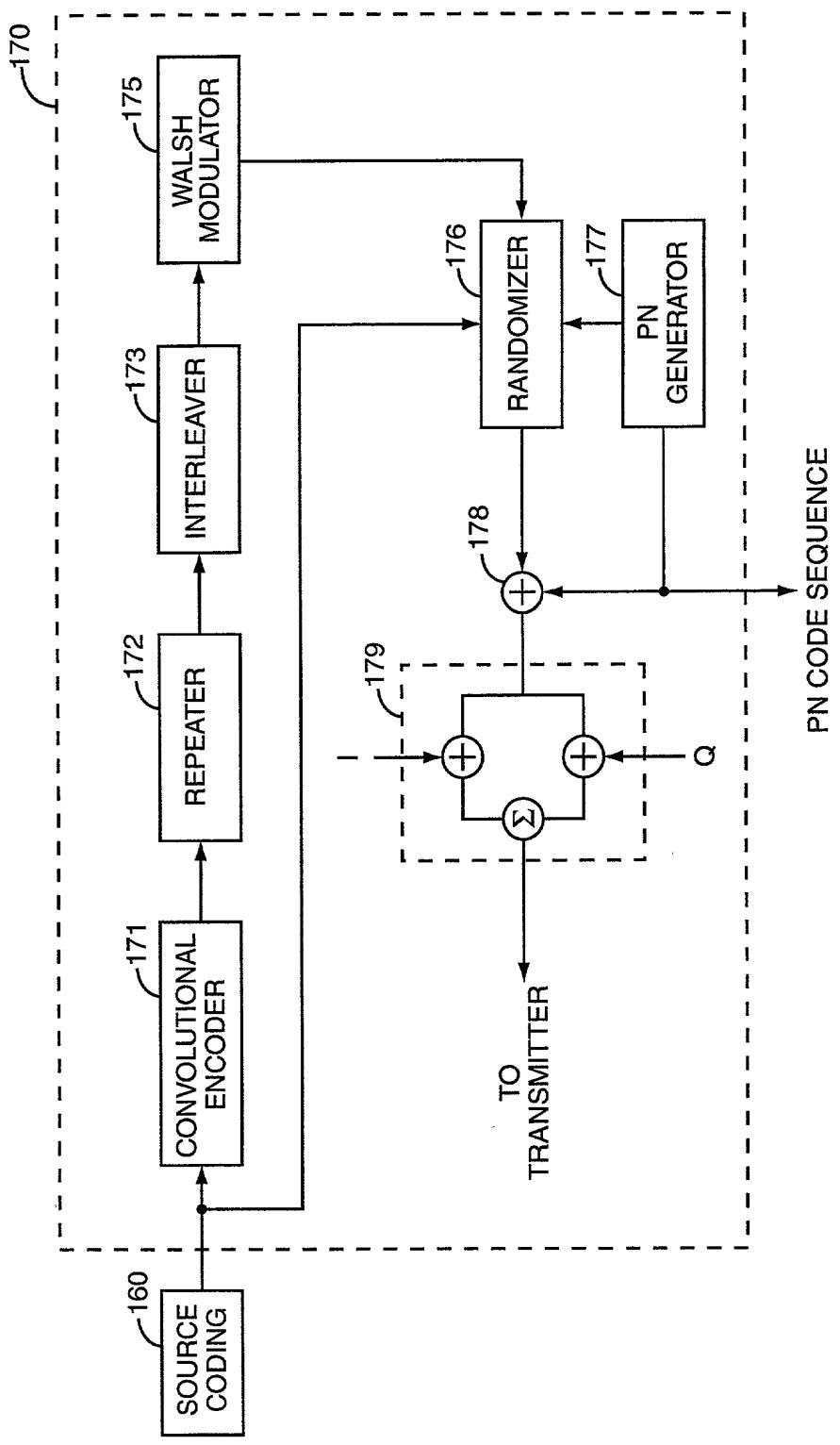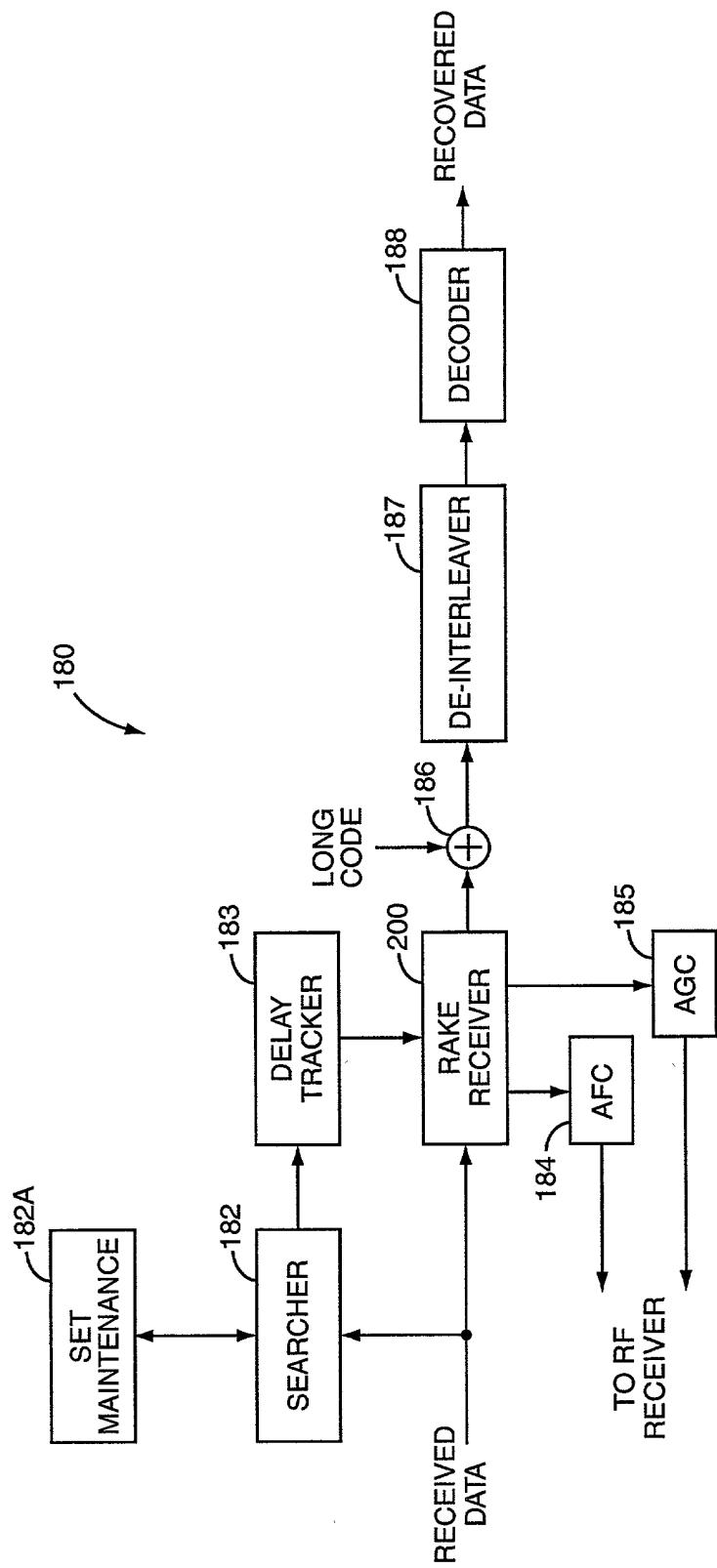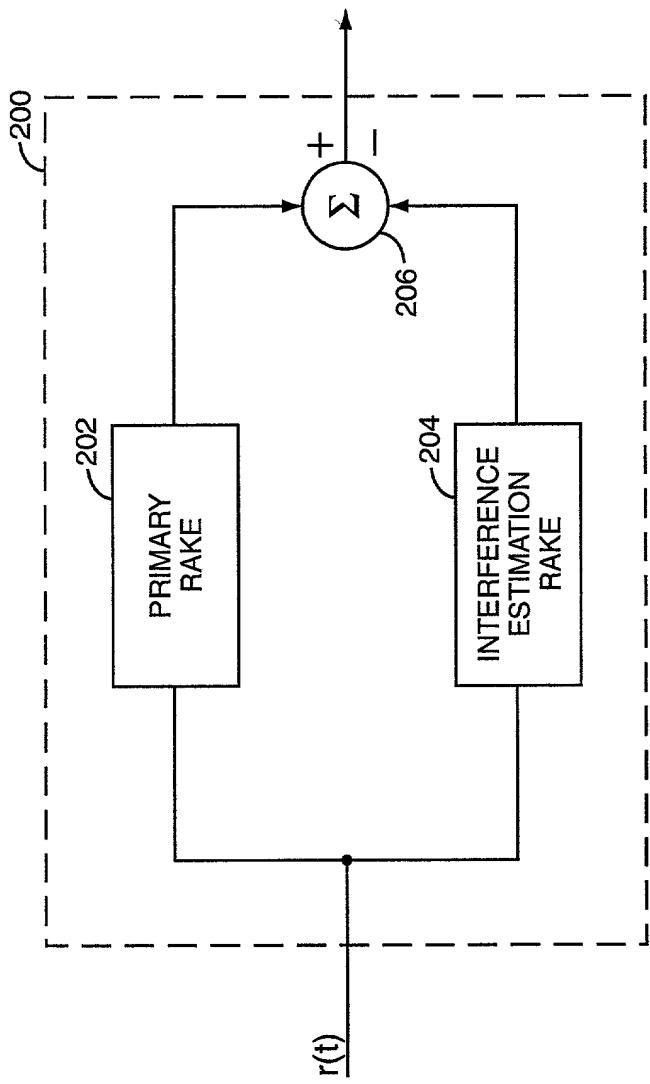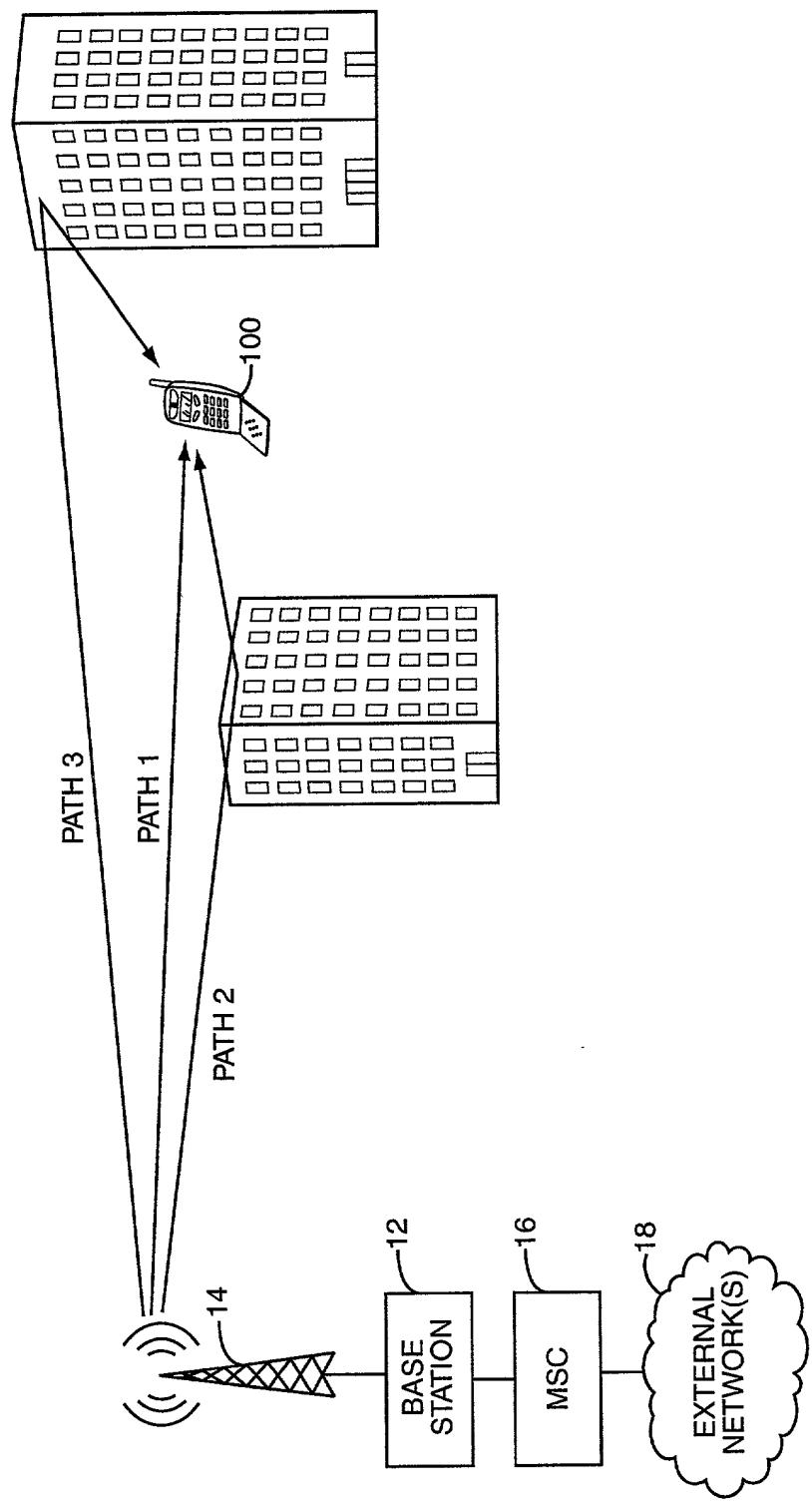
*FIG. 6*
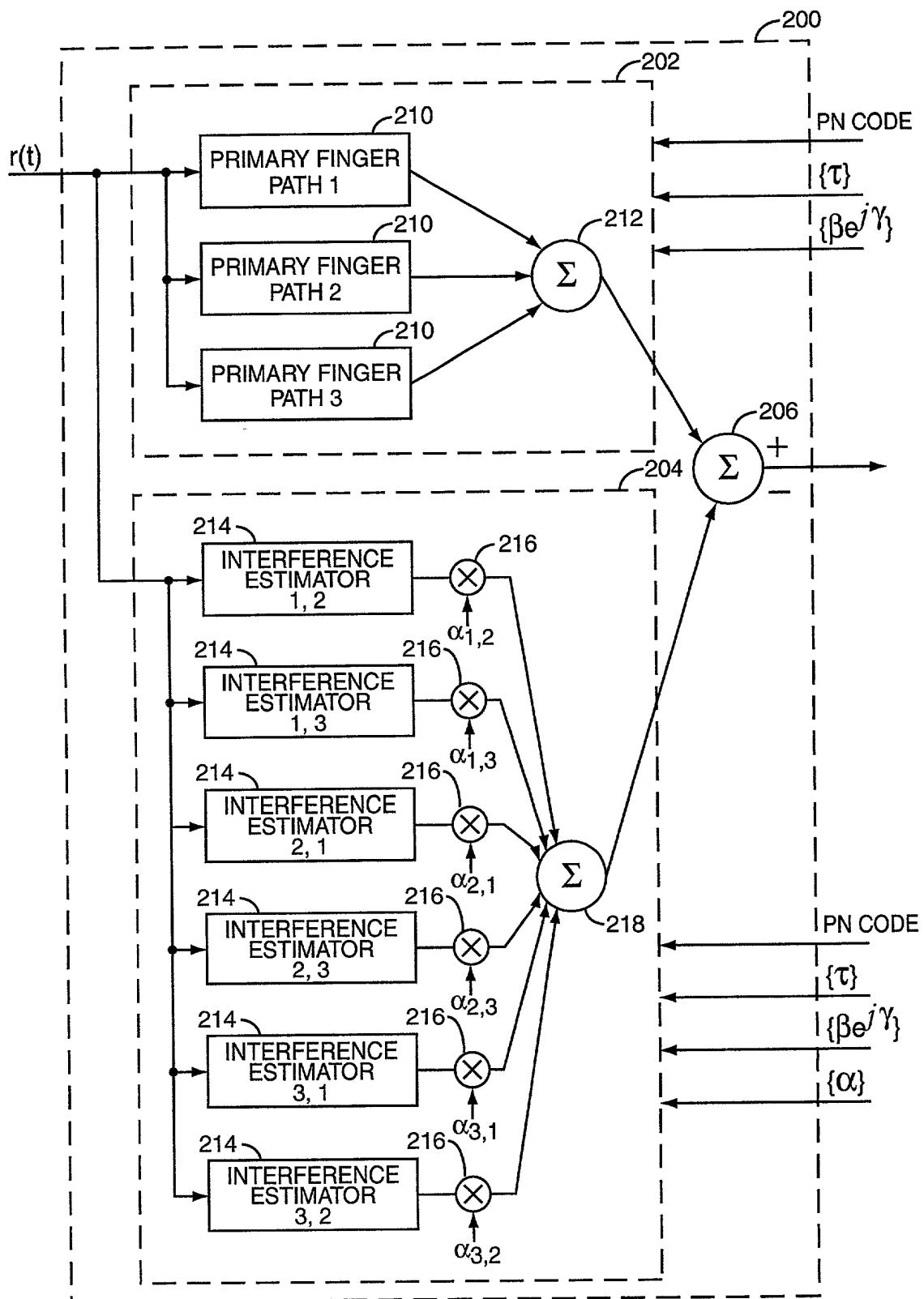
**FIG. 7**
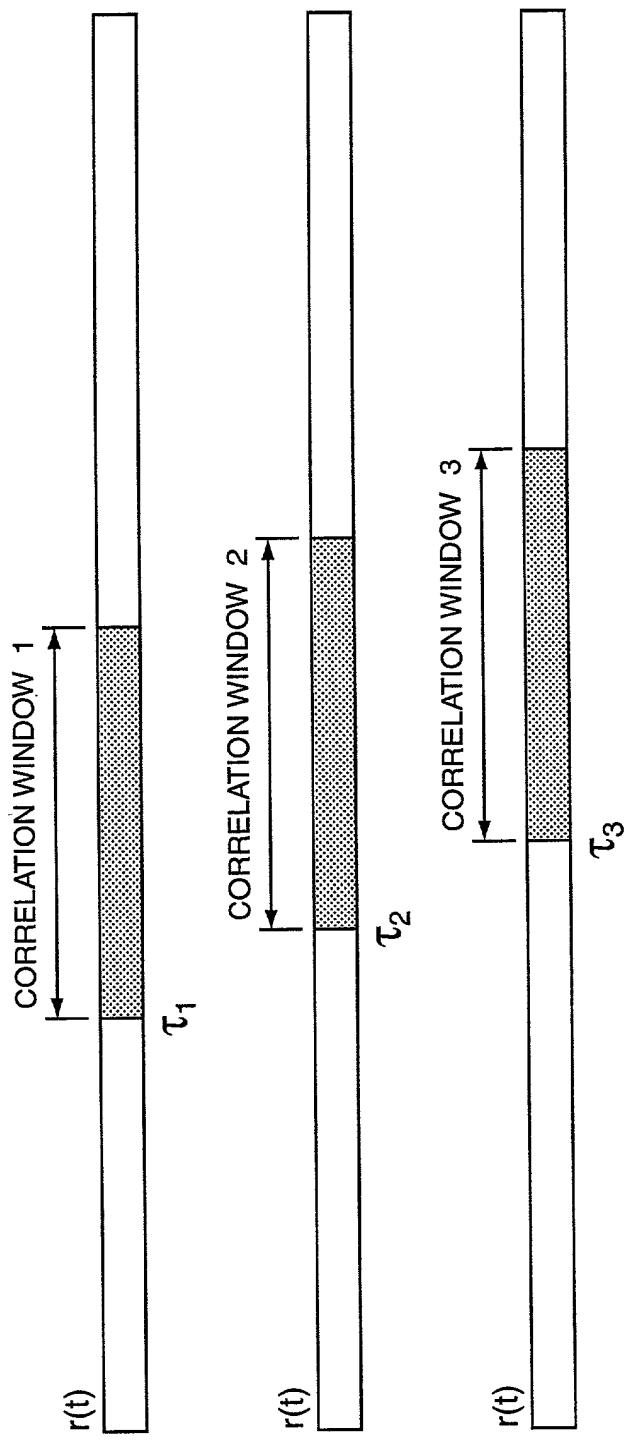
FIG. 8
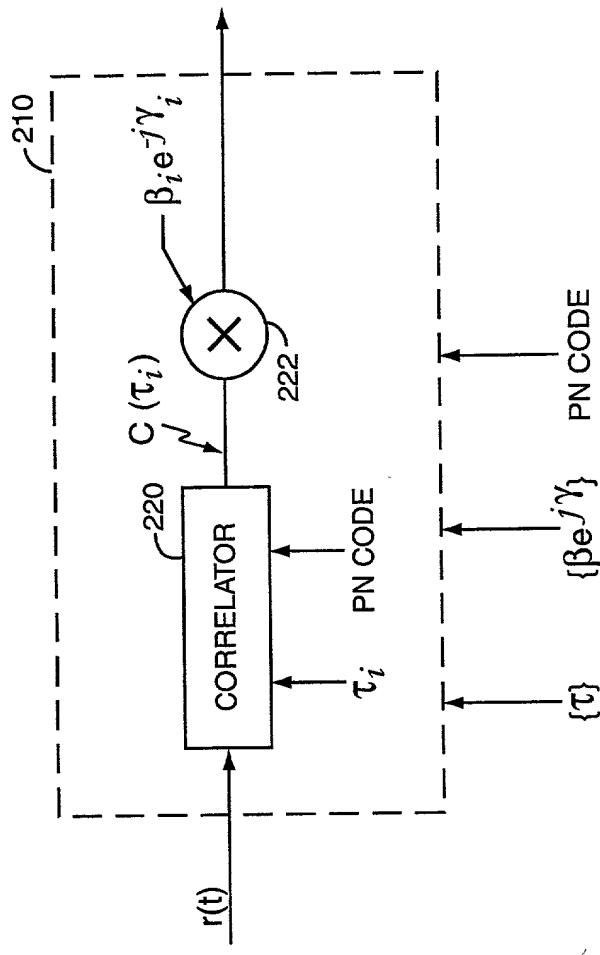
**FIG. 9**
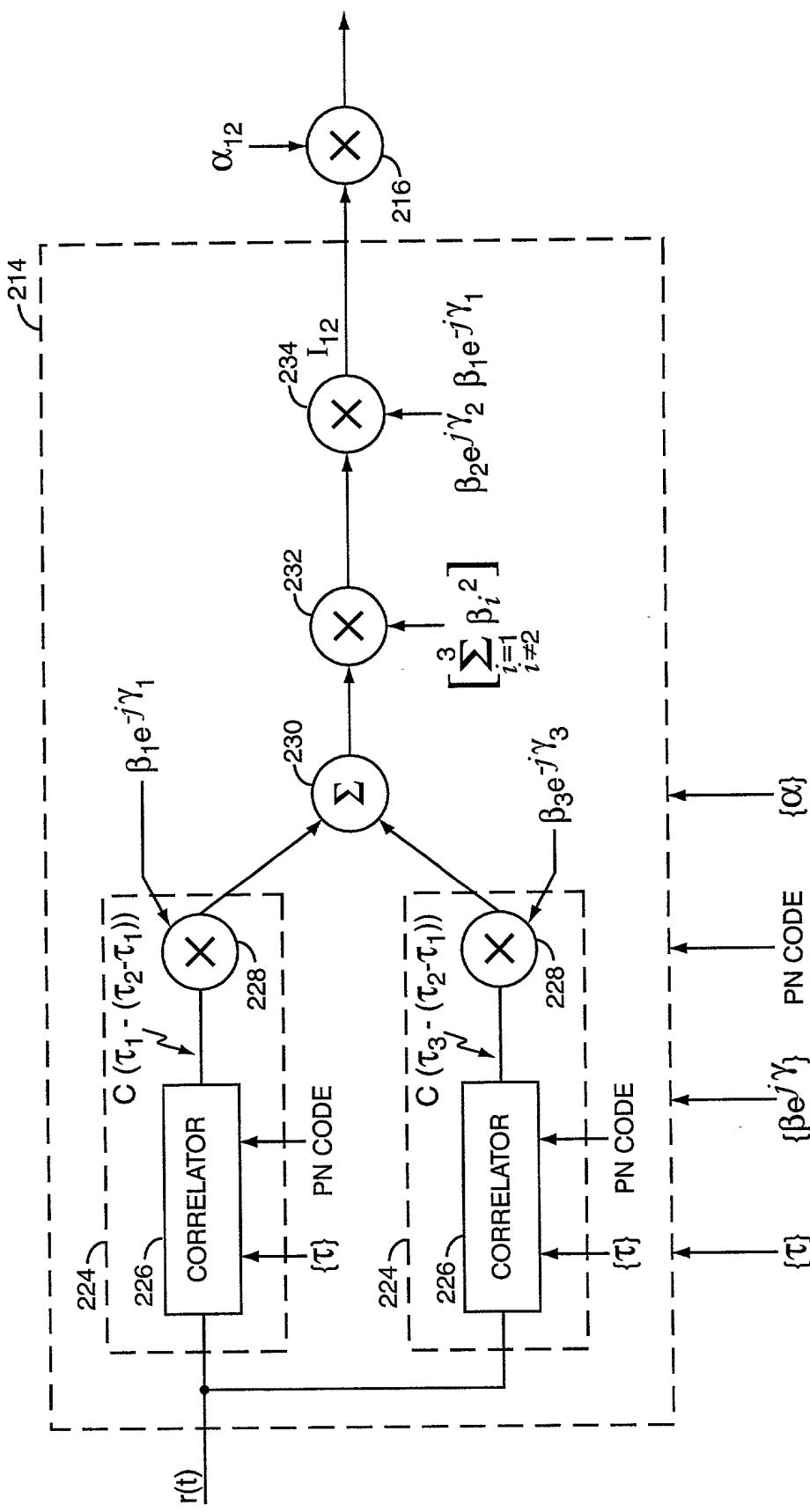
*FIG. 10*

# Declaration and Power of Attorney for Patent Application

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe that I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM, the specification of which

> [ X ]     is attached hereto.

(Check one)

> [   ]     was filed on      _____ as
> Application Serial Number    _____ ,
> and was amended on      _____ .
>                                                     (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me which is material to patentability (as defined in C.F.R. §1.56) in connection with the examination of this application.

I hereby claim foreign benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)                                    **Priority Claimed**

| NONE_____ | _____ | _____ | [   ] | [   ] |
| (Number) | (Country) | (Day/Month/Year Filed) | YES | NO |

| _____ | _____ | _____ | [   ] | [   ] |
| (Number) | (Country) | (Day/Month/Year Filed) | YES | NO |

| _____ | _____ | _____ | [   ] | [   ] |
| (Number) | (Country) | (Day/Month/Year Filed) | YES | NO |

# Declaration and Power of Attorney for Patent Application

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

NONE
_____        _____        _____
(Application Serial No.)        (Filing Date)                  (Status: Patented/Pending/Abandoned)


_____        _____        _____
(Application Serial No.)        (Filing Date)                  (Status: Patented/Pending/Abandoned)


**Power of Attorney:** As a named inventor, I hereby appoint the following agents/attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.


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## Declaration and Power of Attorney for Patent Application

And I also hereby appoint the Attorneys and Patent Agents of **Coats & Bennett, P.L.L.C.,** as identified by **Customer Number 24112** in the records of the United States Patent and Trademark Office and as updated from time to time, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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　　　　　　　First Name　　　　　Middle Name/Initial　　　Last Name

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